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Thermohaline Fingerprints of the Greenland-Scotland Ridge and Fram Strait Subsidence Histories

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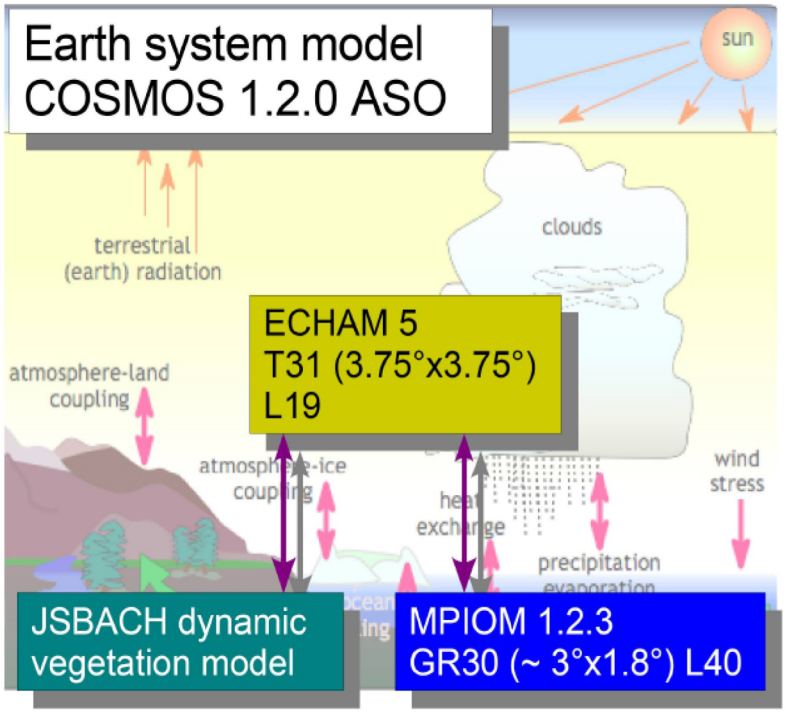
Model: COSMOS-ASO GCM

- Earth System Model COSMOS includes atmosphere model ECHAM5, land-vegetation model JSBACH and ocean model MPI-OM.
- Model setup is based on Miocene (~23–15 Ma).
- Different GSR and FS sill depths represent different tectonic configurations during early-mid Miocene.
- Height of the Antarctic ice-sheet are reduced, Greenland ice-sheet is absent.



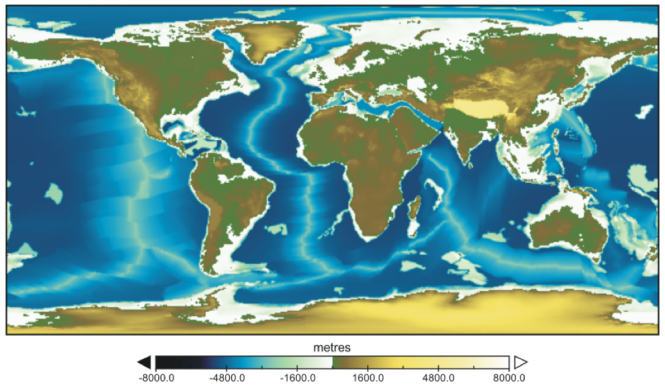
Atmosphere/
Land Surface
3.75˚ x 3.75˚
19 Vertical Layers

Ocean/Sea Ice
3.5˚ x 1.5˚
higher at poles
40 uneven Layers

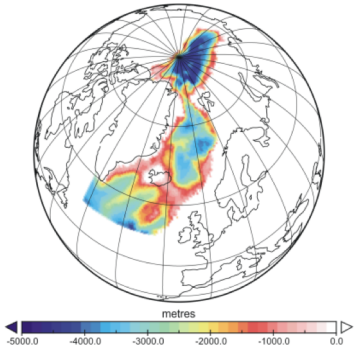
Model boundary conditions

- Model setup includes orography, paleobathymetry, and ice sheet adjustments of Herold et al. (2008).
- Implements regional bathymetric reconstructions (North Atlantic/ Arctic Ocean (Ehlers and Jokat, 2013) and Weddell Sea (Huang et al., 2017)).
- Barents Sea is subaerially exposed and FS is only gateway towards the Arctic.

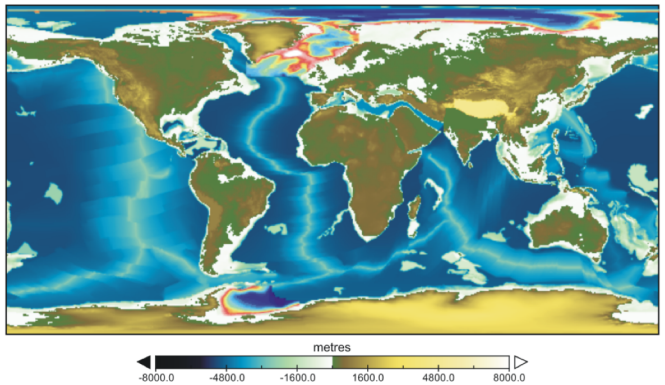
Global topography reconstruction (Herold et al., 2008)



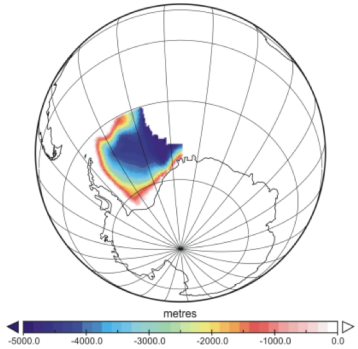
Ehlers and Jokat, 2013



Improved bathymetry reconstructions



Huang et al., 2014



Model experiments

Table 1: List of sensitivity experiments

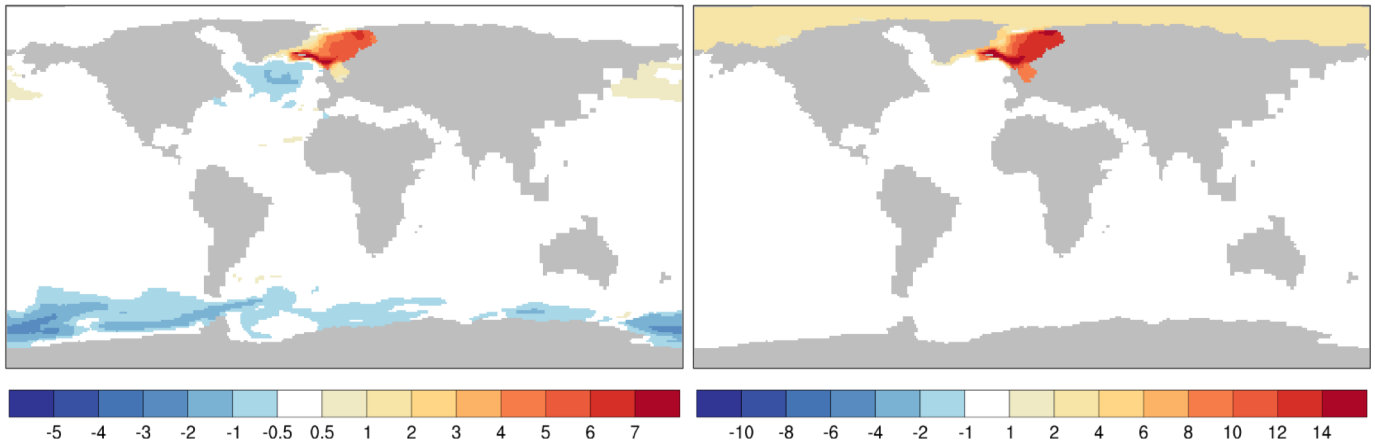
Model Exp.	max. Fram depth (m)	max. GSR depth (m)	Atmos. CO_2 (ppm)	Length of simulation (kyrs)
MIO_450	~2,500 m	960 m	450	3.3
MIO_FS50	50 m	960 m	450	2.0
MIO_GSR40	~2,500 m	40 m	450	2.0
MIO_FS50_GSR40	50 m	40 m	450	2.0

Table 2: List of scenarios

Title	Anomaly of experiments	GSR depth change (m)	FS depth change (m)
$\Delta GSR\_FS_{shallow}$	MIO_FS50 – MIO_FS50_GSR40	~960 – 40	50
ΔGSR_FS_{deep}	MIO_450 – MIO_GSR40	~960 – 40	~2500

Singular effect of GSR deepening for a shallow FS

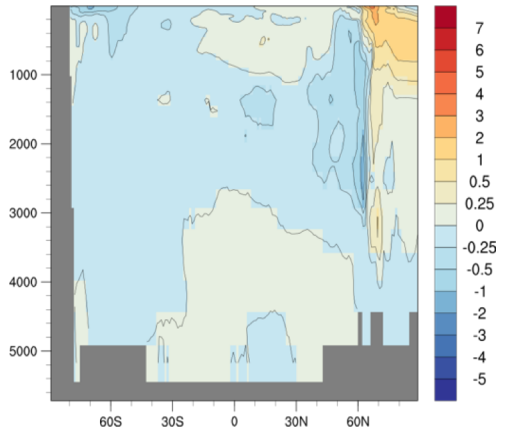
SST $\Delta GSR\_FS_{shallow}$ SSS



Warming and a salinity increase in the Nordic Seas/ Arctic Ocean.

- Convection sites shift to the north off Iceland. NADW formation takes place at cooler temperatures.
- The deep overflow of dense, cold water results from newly established NADW formation sites north of Iceland.

zonal temperature

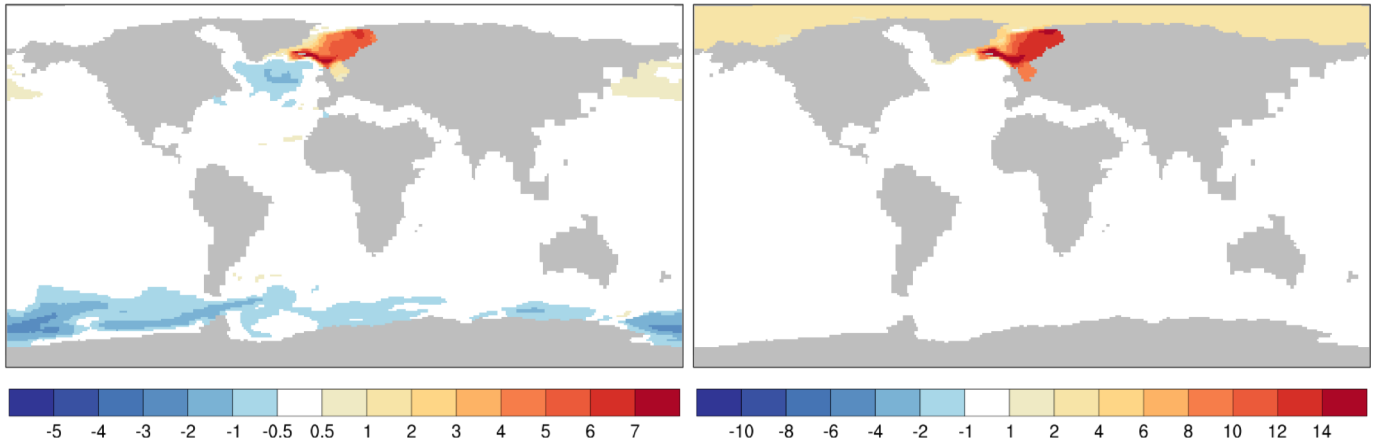


Singular effect of GSR deepening for a shallow FS

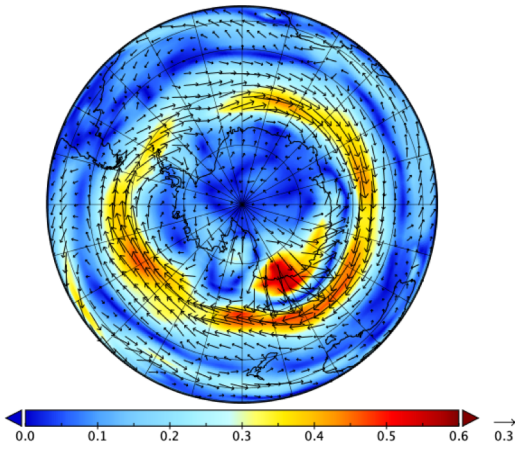
SST

$\Delta GSR\_FS_{shallow}$

SSS

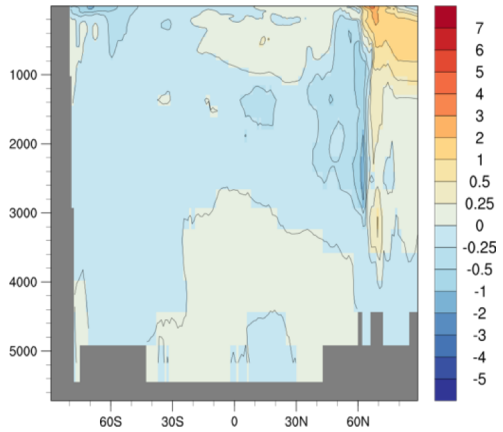


Annual mean wind (m/s)

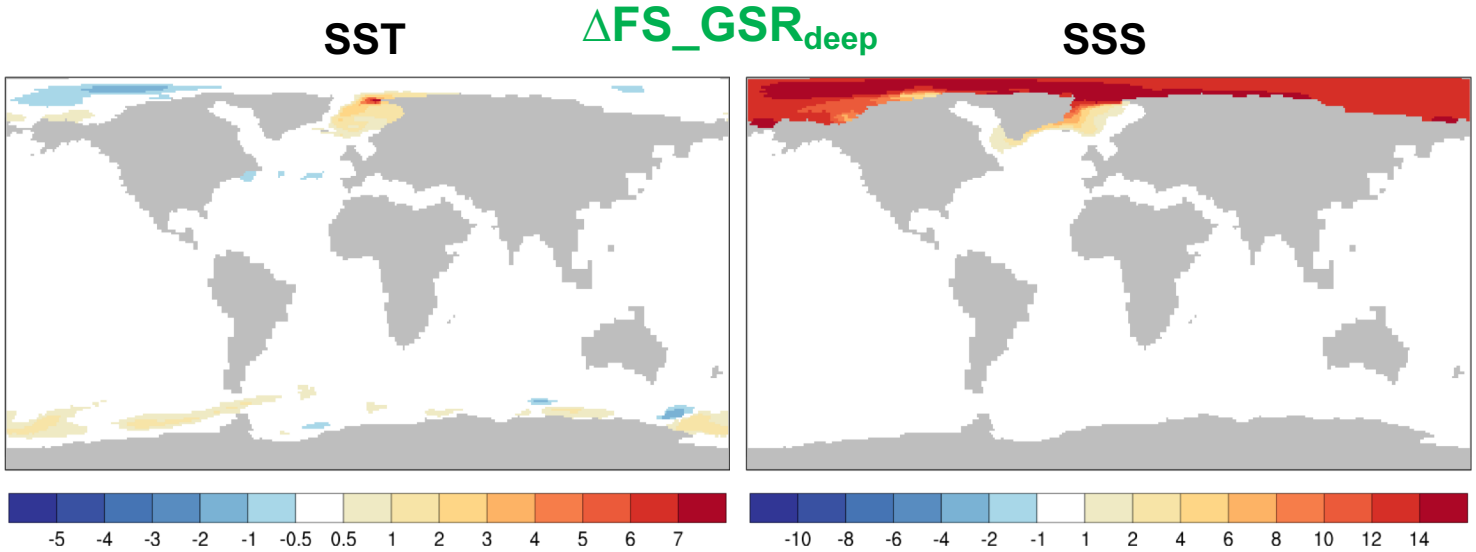


- The associated cooling in the deep ocean and upwelling to the Southern Ocean surface causes a cooling (up to –3 K) in the southern high latitudes
- Boosted by enhanced westerlies.

zonal temperature

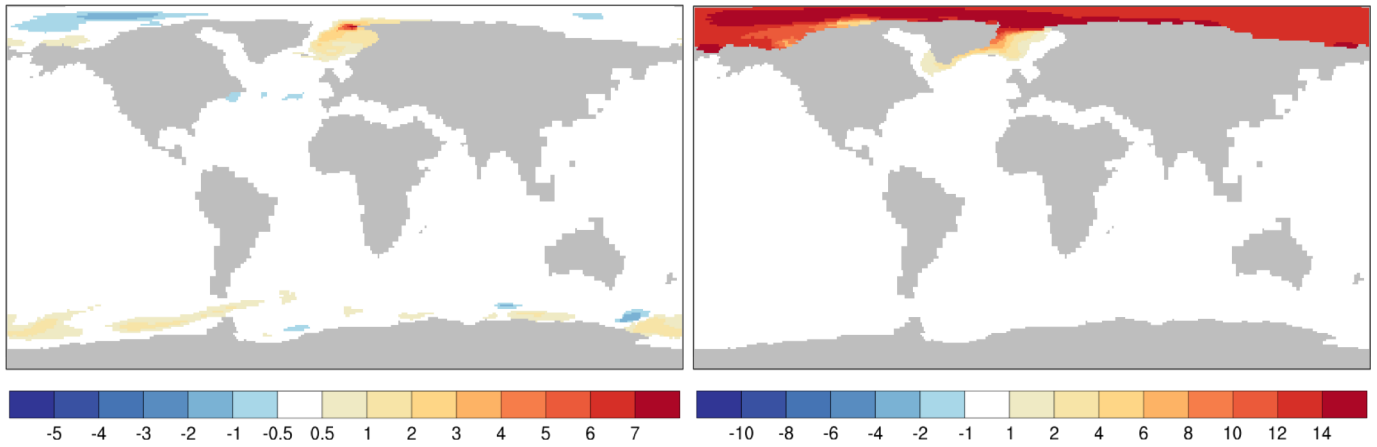


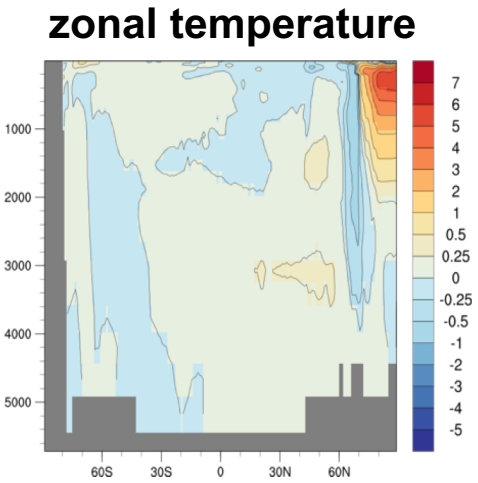
Singular effect of FS deepening for a deep GSR



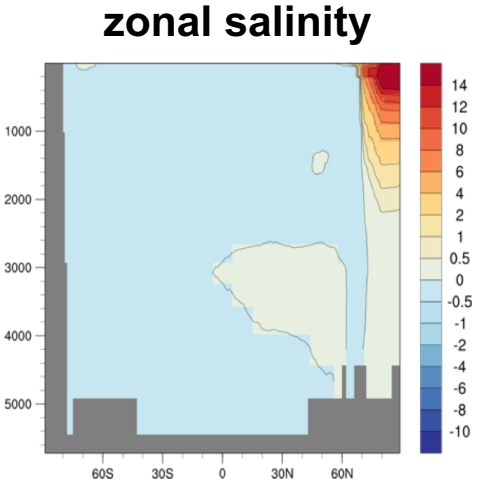
- Warming and a salinity increase in the Nordic Seas that is less pronounced than in $\Delta GSR\_FS_{shallow}$.
- Unaltered temperatures and a stronger salinity increase in the Arctic.
- Due to the bulk inflow of Atlantic water, the Arctic Ocean becomes more saline.

Singular effect of FS deepening for a deep GSR





- Strong salinity increase in the Arctic increases the density of NADW by entrainment. This enhances the contribution of NADW to the abyssal ocean and at the expense of the colder southern source water component.
- These relative changes largely counteract each other and cause a negligible warming in the Southern Ocean.



Geological constraints and Outlook

- The time when GSR deepening initiated (~36 Ma), the FS was shallow. (Jokat at al., 2016)
- Initial oceanic crust within the FS formed between 24 to 21 Ma. (Jokat et al., 2016)
- GSR sill is below sea level (below ~300 m) between ~20-24 Ma. (Stärz et al., 2017)
- FS subsidence for a deep GSR is likely at time period younger than 18 Ma. (Jokat et al., 2008; Ehlers and Jokat, 2013; Stärz et al., 2017)

Based on geological evidence and tectonic constraints:

Phase 1: GSR sill subsidence towards a deep gateway configuration for a shallow FS sill depth at ~20±3 Ma (Jokat at al., 2016)

Phase 2: the opening of FS initiated when GSR is already deeper than ~300 m between ~20-24 Ma. (Stärz et al., 2017)

THANK YOU FOR YOUR ATTENTION!!!

References

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